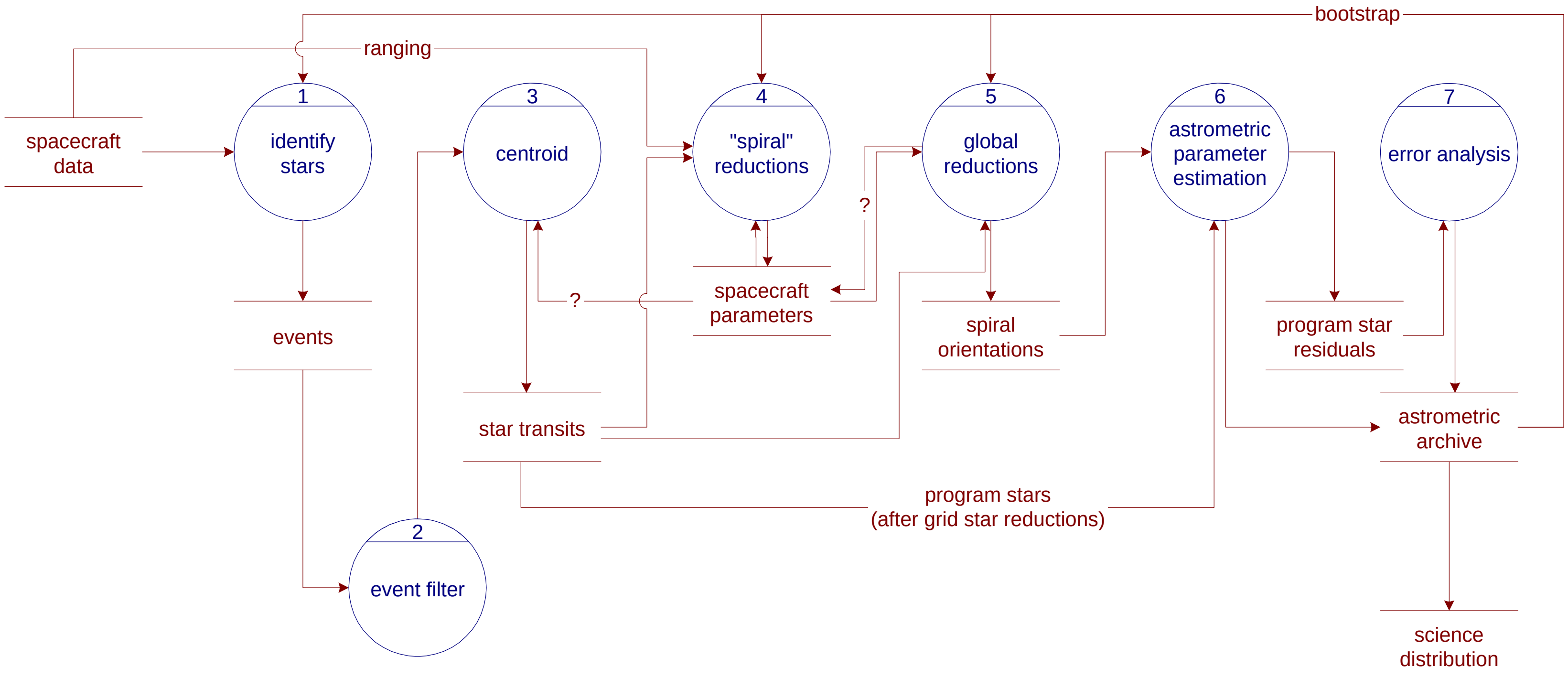
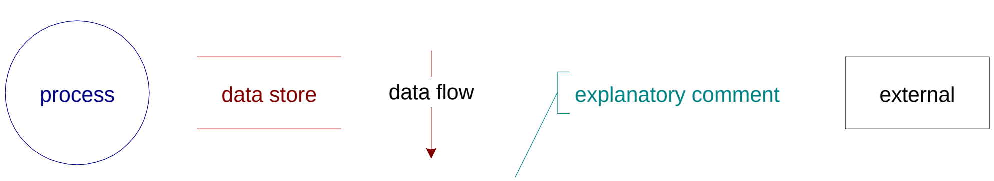
FAME Data Reduction Overview DFD:
Astrometric Pipeline

19 March, 2001



Symbol Key:



Identify Targets

- Objective: use target catalog and knowledge of spacecraft rotation to identify targets.
- Tasks:
  - Calibrate raw pixel data.
    - known CCD effects (e.g., variations in pixel sensitivity, etc.)
  - Identify type of object.
  - Check for anomalies.

Centroid

- Objective: determine centroid & PSF parameters for targets.
- Task: using all events for a given star during the same observation episode (the time during which a given star is in the field of view on successive rotations of the s/c), do weighted least squares (WLS) fit of the centroid and PSF parameters for each star.
- WLS parameters
  - centroid model(s)
  - PSF model(s)
  - stellar parameters (spectral type, magnitude)
  - CCD
  - star multiplicity analysis
- Calculate residuals.
- Flag anomalies.
- Photometric fitting.

Spiral Fitting

- Objective: a rigid spiral
  - Uncertainty in angular separations is small compared to single-measurement uncertainty.
- Yield: spacecraft rotation model for each spiral segment.
- Task: perform weighted least squares fit of the spacecraft orbit and spin dynamics and instrument parameters.
  - Select events, form spiral segments.
  - Integrate equations of motion.
  - Integrate variational equations.
  - Use *a priori* fiducial star coords, then bootstrap.
- WLS parameters: see Spin Dynamics
- Optimal spiral segment length TBD.
- Spiral segment orientation not well known (but that's okay for now).

Global Fitting

- Objective: tie the spiral segment rotation models together.
- Yield: a single spacecraft rotation model.
- Task: weighted least squares fit of fiducial stars (or subset of fiducial stars).
- WLS parameters
  - Fiducial star astrometric parameters
  - Spiral segment orientation parameters
- Discard (and replace) anomalous stars.
- Check: repeat for different sets of fiducial stars.
- Inertial frame orientation.

Astrometric Fitting

- Objective: determine astrometric parameters for each target star
- Yield:
  - astrometric parameters
  - residuals
    - Look for peculiar motions (planets!)
- Tasks:
  - Sort by object
  - Weighted least squares fit
    - Do one star at a time.
    - Use all observations (i.e., data span is mission length).
  - Check PSFs for anomalies
    - asymmetry
    - color variations
    - size variations
  - Identify "interesting" stars (anomalous residuals).
  - Search residuals of "interesting" stars for periodicities.

Spin Dynamics Issues (1 of 4)

- Stochastic and other Hard-to-Model Perturbations
  - Fuel sloshing
  - Variability of solar irradiance
    - variations on all timescales
    - short-term fluctuations are stochastic
    - variation ~0.1 percent over long timescales
    - variation ~0.01 percent over short timescales
  - Earth radiation pressure
    - visible
    - infrared
    - variability due to weather
    - complicated torques
      - spacecraft not protected by shield
      - optical ports
      - AKM hole
  - Nutation damping mechanism stiction and/or other undesirable behaviors
  - Magnetic torques near magnetopause

Spin Dynamics Issues (2 of 4)

- Solar Shield
  - Shield (panels, teflon tape, & webbing) & flattop albedos
    - variable over time as materials age
    - spatial inhomogeneities
    - AKM: hole or cover?
  - Variations in effective shield angle
    - nonuniform in circumference
    - slow variation over time
    - fast variation — flapping modes (eclipses)
  - Shield geometry perturbations
    - solar panels
      - potato chipping
      - dynamic modes
        - radial (flapping)
        - twisting
        - what are the timescales for damping?
    - interpanel membranes
      - sagging
      - flapping?

Spin Dynamics Issues (3 of 4)

- Thermal radiation torques
- Axis of shield misaligned with spacecraft spin axis
- Trim tab problems
  - nonuniform axis directions
  - mechanism slop?

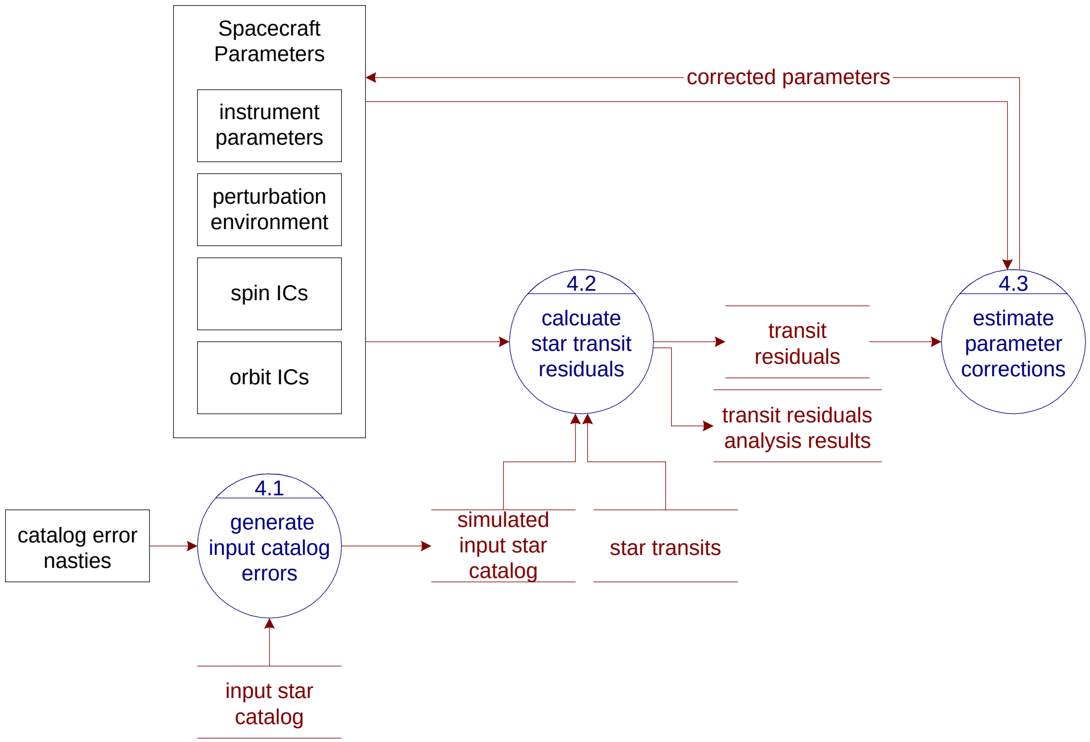
- Perturbations Due to Events
  - Eclipses
  - Geotail particle bursts
    - "wind" gusts
    - potentials across spacecraft surfaces cause electrical currents which cause magnetic torques
      - caused Echo spinup
    - very large bursts from fast CME events
      - a few times per year around solar max
      - potential for spacecraft damage?
  - Magnetopause crossings
    - relatively rare at geosynch (a few times a year)
    - short duration (~15 min) exposure to full blast of the solar wind
  - Micrometeoroid hits

Spin Dynamics Issues (4 of 4)

- Other Smooth Perturbations
  - Spin axis not aligned with principal axis
  - Spacecraft thermal radiation torques
    - Sun shield
    - thermal radiators
    - telescope viewports
  - Gravity gradient torques
  - Movement of center of gravity as fuel is expended
  - Variations of Sun direction due to Sun-tracking dynamics
  - Variation of solar radiation pressure as spacecraft orbits around the Earth
  - Magnetic torques
  - Lunar torques
  - Jitter

FAME Spiral Segment Reduction DFD: Overview

19 March, 2001



Notes

A "transit" consists of two parts: an in-scan precise timing (< 600 µas) and a less-precise (~5-15 mas) cross-scan position.

4.1. It will eventually be not only useful but essential that we introduce various kinds of errors into the input catalog. This allows us to quantify our (in)sensitivity to input catalog systematics.

FAME Spiral Segment Reduction DFD:
Generation of Star Transit Residuals

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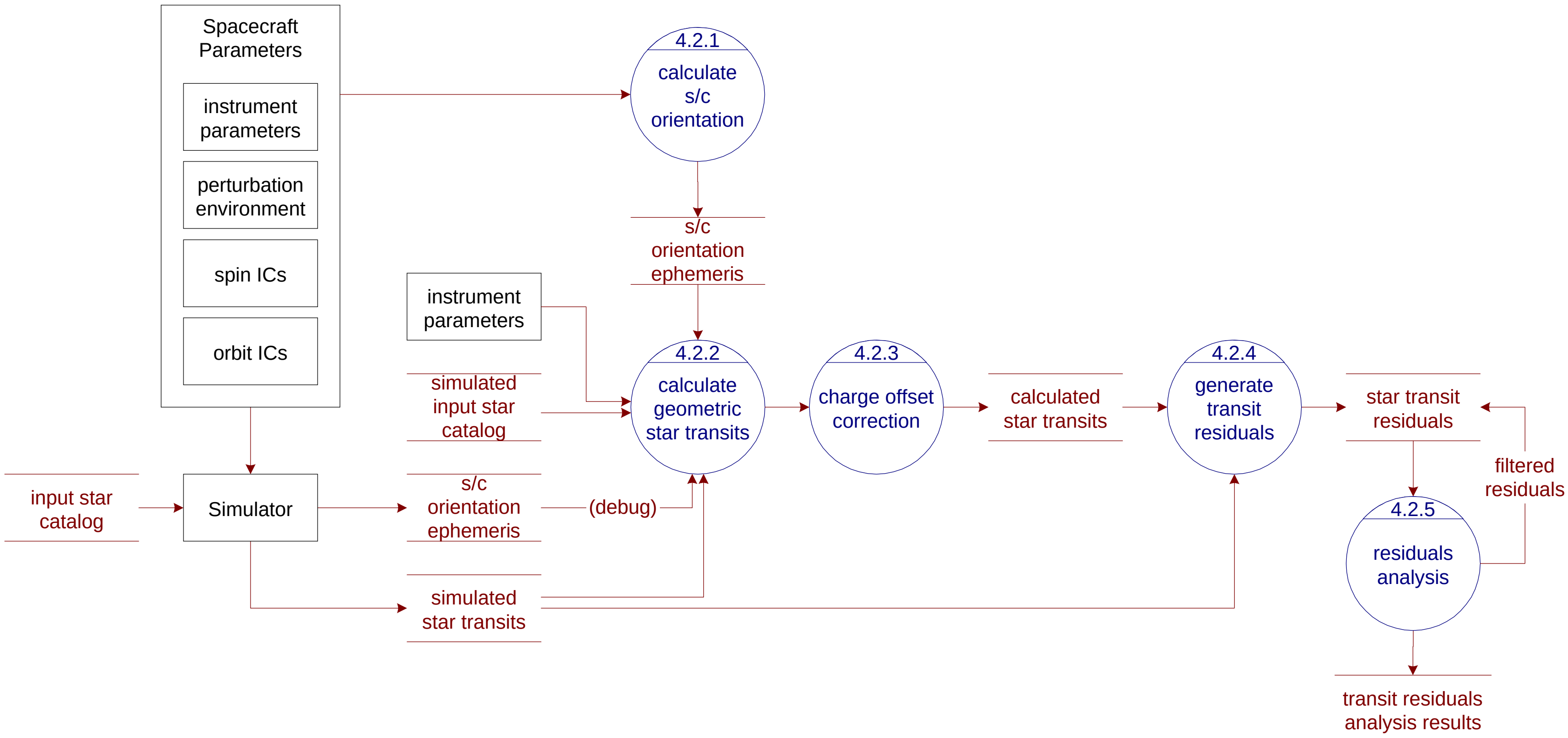


Process Notes

4.2.2. Here is where, on a star-by-star basis, we calculate (predict) the star transit times.

4.2.3. This module merely subtracts the predicted transit times from the "actual" transit times obtained from the Simulator (or, much later, the instrument), producing the transit residuals for a given "spiral" segment of data.

4.2.4. A frequency analysis of the transit residuals will be very illuminating. Most systematic errors will be periodic. This is also the place to look for outliers and other problems, before performing the parameter estimation.

FAME Spiral Segment Reduction DFD: Calculation of Star Transits

19 March, 2001

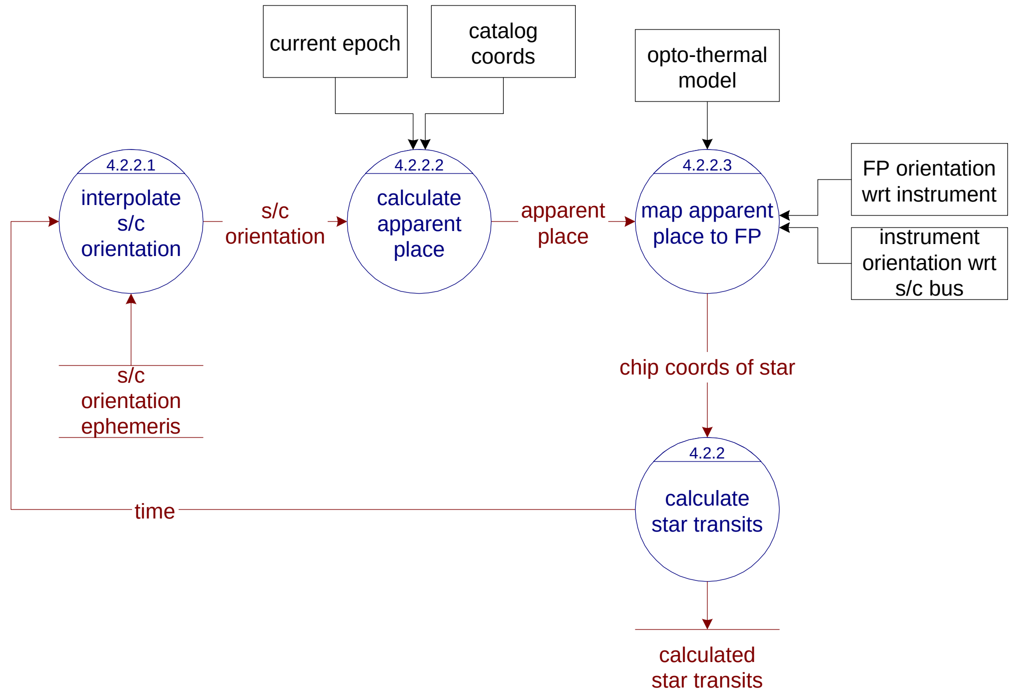
Process Notes

4.2.2.1. To start, we can use simple analytical formulas to calculate the spacecraft orientation as a function of time. Later, we can substitute numerical integrations to accomplish the same task. For a given "spiral" segment, a single, moderately high resolution integration will be done, producing an orientation ephemeris. Interpolation of the ephemeris then gives the orientation for any given time within that data segment.

4.2.2.2. This module converts catalog coordinates (equatorial and/or ecliptic) to apparent place.

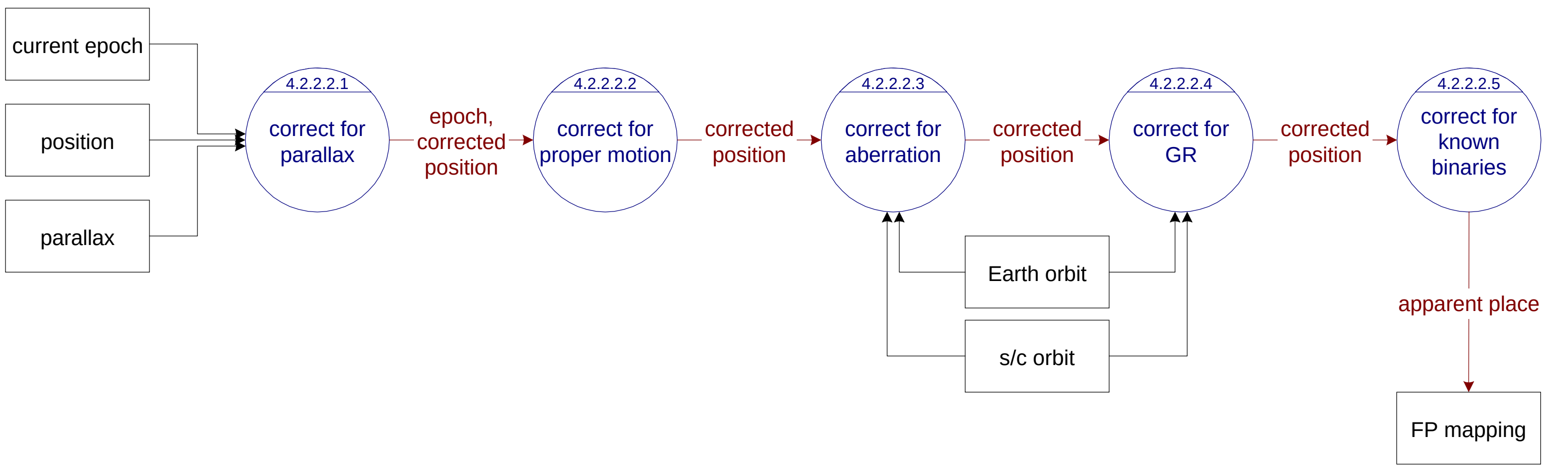
4.2.2.3. This module maps apparent places to perturbed focal plane coordinates. What is needed are the opto-thermal model for the optical transformation, the spacecraft body frame orientation wrt the sky (inertial frame), the orientation of the instrument frame wrt the spacecraft bus (body) frame, and the orientation of the focal plane assembly wrt the instrument frame. There will be separate FPA orientations for the two viewports, in order to allow the plane defined by the two viewport direction vectors to be non-perpendicular to the spin axis.

4.2.2. This is the driving process. The transit calculation process is fundamentally a root-solving algorithm. The function whose root, or zero-crossing, is to be found is the displacement of a given star from a given CCD "wire" (or last row). This displacement is, via processes 4.2.2.1 through 4.2.2.3, a function of a single parameter, time. Hence, we may employ a simple one-dimensional root-finding algorithm. The modified secant algorithm is nearly as fast as Newton's method but has the advantage of always converging.



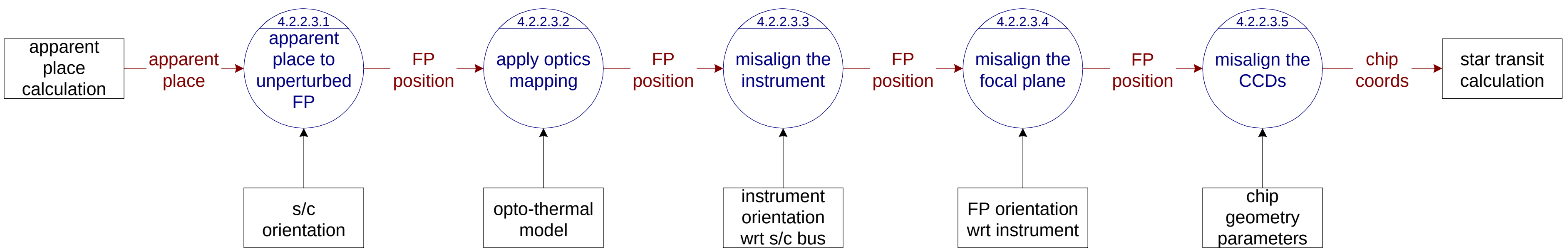
FAME Spiral Segment Reduction DFD:
Catalog Position to Apparent Place

19 March, 2001



FAME Spiral Segment Reduction DFD:
Apparent Place to Focal Plane Position

19 March, 2001

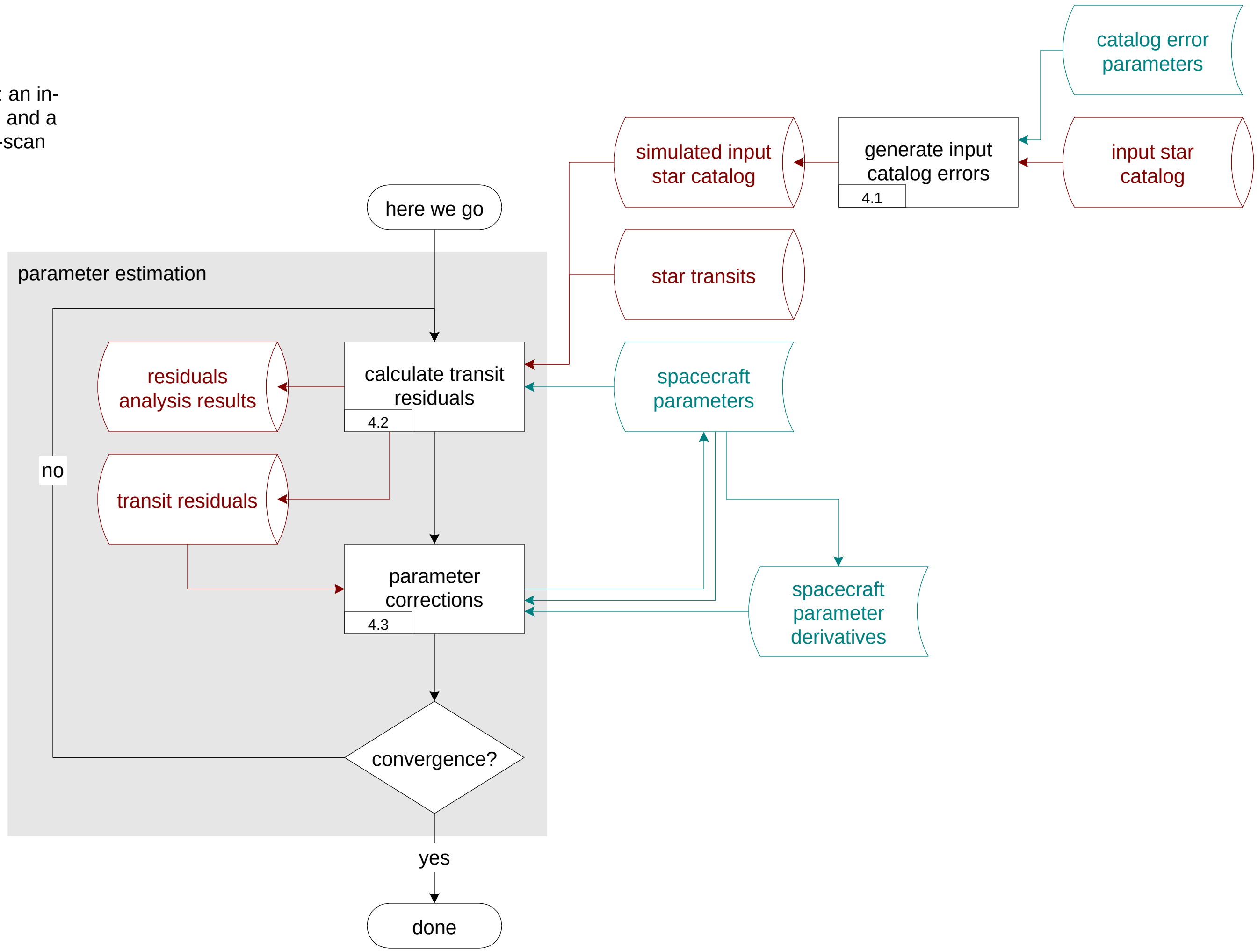


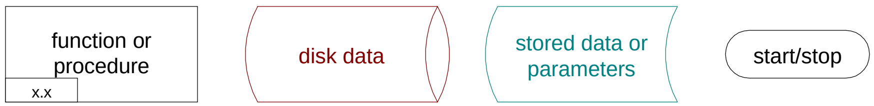
FAME Spiral Segment Reduction Flowchart: Parameter Estimation

19 March, 2001

Note

A "transit" consists of two parts: an in-scan precise timing (< 600 µas) and a less-precise (~5-15 mas) cross-scan position.





FAME Spiral Segment Reduction Flowchart: Generation of Star Transit Residuals

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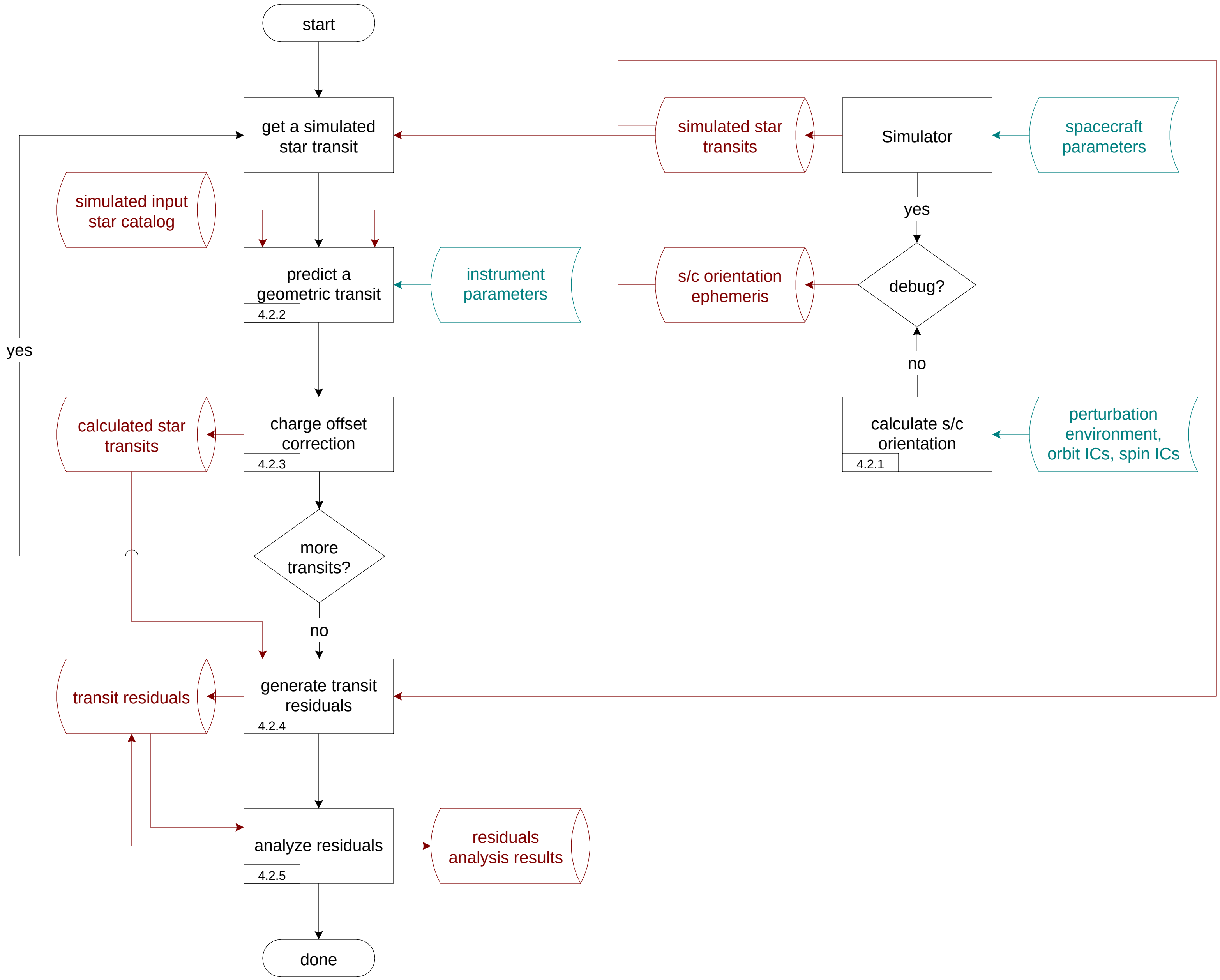
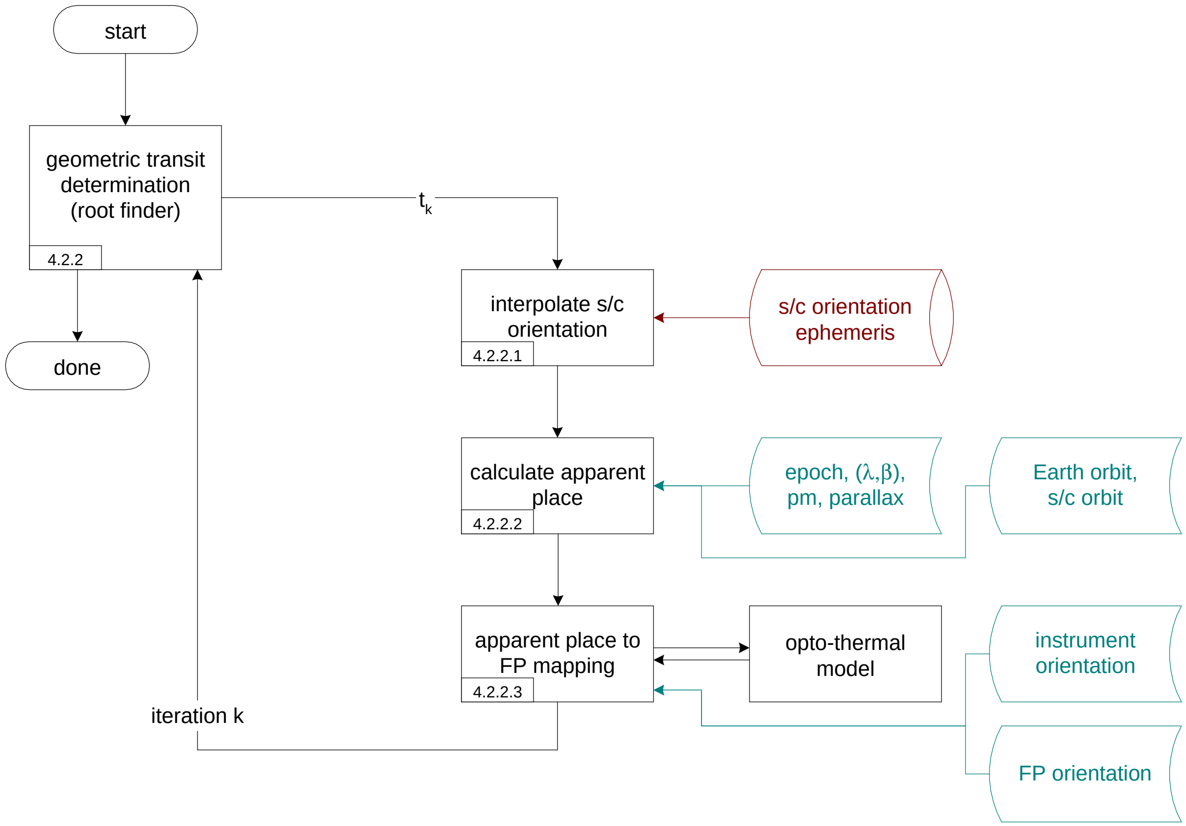


FAME Spiral Segment Reduction Flowchart: Calculation of Star Transits

19 March, 2001



FAME Spiral Segment Reduction Flowchart: Catalog Position to Apparent Place

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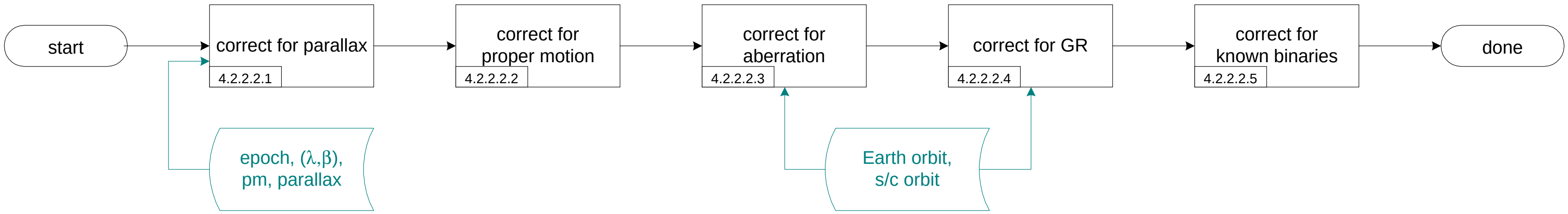

FAME Spiral Segment Reduction Flowchart:
Apparent Place to Focal Plane Position

19 March, 2001

Note

4.2.2.3.1. The transformation to the "unperturbed" focal plane refers to the simple mapping from apparent place to the focal plane before any of the "perturbing" transformations have been applied, namely the optical mapping and the various misalignments specified in the flow following this (4.2.2.3.1.) module. When this is looked at in detail, we may decide to combine this with the optics mapping module.